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(54) Infrared electronic thermometer and method for measuring temperature

Elektronisches Infrarotthermometer und Verfahren zur Temperaturmessung

Thermomètre électronique à infrarouge et procédé de mesure de la température

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- **PATENT ABSTRACTS OF JAPAN vol. 002, no. 084 (E-042), 8 July 1978 & JP 53 047884 A (MATSUSHITA ELECTRIC IND CO LTD), 28 April 1978,**

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Description

Field of the Invention:

[0001] This invention relates to an electronic thermometer and more particularly to a noncontacting infrared electronic thermometer and method for measuring the temperature of an object.

Background of the Invention:

[0002] The temperature of an object, such as the human body, can be determined by using a contact thermosensor or by measuring the naturally radiated energy from the body such as the radiated energy in the far infrared range. The infrared radiation is directly related to temperature of the object and can be utilized to determine the temperature of the body.

[0003] An exemplary temperature measuring apparatus utilizing a pyroelectric infrared radiation sensor is disclosed in JP-A-57 035740. The apparatus incorporates a one-shot shutter to obtain a transient output from the sensor and compensates for the temperature of the shutter by processing the output of the sensor with a shutter temperature signal determined by means of a thermistor. Otherwise the description of the apparatus in JP-A-57 035740 is not especially complete.

[0004] A further remote reading infrared thermometer is more fully described in US-A-4 005 605. The instrument is designed to be hand held and has at its forward end a sensor cavity defined by a conical housing having its apex pointing forwards and having a relatively small opening at its apex for admitting infrared radiation to the cavity. A radiation detector is mounted within the cavity to receive infrared radiation from an object when the instrument is pointed at the object and when a concave radiation-focussing mirror within the cavity is appropriately positioned. The mirror is movable and is normally positioned so that the radiation sensor receives ambient infrared radiation from the walls of the cavity, a trigger being provided to move the mirror so as to cause radiation from an external object to be focussed on the radiation sensor. A thermistor is also provided in the cavity for deriving an ambient temperature signal. The electronics of the instrument processes signals from the radiation sensor representative of the cavity temperature and the object temperature with the thermistor signal to derive a fully compensated temperature measurement.

Object and Summary of the Invention:

[0005] It is an object of the present invention to provide a new and improved noncontacting electronic thermometer which is accurate, reliable and economical to manufacture.

[0006] According to one aspect of the present invention there is provided a thermometer comprising: a housing; a pyroelectric sensor carried by said housing and responsive to infrared radiation for generating an electrical signal which exhibits a transient response upon receipt of said radiation; directing means, carried by said housing, in optical alignment with said sensor, for directing infrared radiation from an object, the actual temperature of which is to be measured, to impinge upon said sensor, said directing means including an elongated guide of predetermined length having an outer end to receive infrared radiation from the object to be measured and an inner end in operative alignment with the sensor, said waveguide being interconnected to said sensor so as to be in thermal equilibrium therewith and having a smooth and shiny interior surface of low emissivity to facilitate transmission of infrared radiation, and an outer surface; enabling means, carried by said housing, for enabling response of said sensor to said radiation; and electrical means carried by said housing and responsive to said transient response of said signal for processing said signal to develop an indication of the actual temperature of said object.

[0007] In accordance with another aspect of the present invention there is provided a method for measuring the temperature of an object with a thermometer having a housing, arranging for the housing to carry a pyroelectric sensor so as to be responsive to infrared radiation for generating an electrical signal which exhibits a transient response upon receipt of said radiation form the object along an elongated guide having a smooth and shiny interior surface of low emissivity to facilitate transmission of infrared radiation being of predetermined length receiving the said infrared radiation from the object within the guide through an outer end thereof, ensuring the guide is in operative alignment with the sensor arranging for the waveguide to be carried with the sensor so that the sensor is in thermal equilibrium therewith, utilising enabling means carried by the housing to enable response of said sensor to said radiation, and enabling electrical means carried by said housing and being responsive essentially only to said transient response of said signal so as to processes said signal to develop an indication of the actual temperature of said object.

[0008] Therefore, the invention may provide a noncontacting electronic thermometer for measuring the temperature of an object virtually instantaneously.

[0009] The noncontacting electronic thermometer may be used for medical use which is compact, inexpensive and convenient and easy to use.

[0010] Alternatively, there can be provided a heat detector for medical use which detects warm spots on the surface of the skin.

[0011] Furthermore, there can be provided a method for measuring the temperature of a body utilizing a high-speed pyroelectric infrared sensor and a relatively slow speed ambient temperature sensor.

[0012] The above and other features of the present invention are set forth in the appended claims and will become clear to those possessed of relevant skills from

consideration of the following description of exemplary embodiments given with reference to the accompanying drawings.

Brief Description of the Drawings:

[0013]

Figure 1 is a diagrammatical broken away perspective view of the electronic thermometer of the present invention.
Figure 2 is a diagrammatical schematic view of the electronic thermometer of the present invention.
Figure 3 is a diagrammatical longitudinal sectional view of the pyroelectric sensor.
Figure 4 is a diagrammatical sectional view of the pyroelectric film material of the pyroelectric sensor of Fig. 3.
Figure 5 is a diagrammatical longitudinal sectional view of another embodiment of a pyroelectric sensor.
Figure 6 is a diagrammatical sectional view of the beam aiming element of Fig. 2.
Figure 7 is an electrical schematic diagram of the amplifier circuit of Fig. 2.
Figure 8 is a real time graphical representation of the operational sensor signal.
Figure 9 is a diagrammatical schematic view of a calibration assembly for the electronic thermometer.
Figure 10 is a graphic view of the wave forms produced in the calibration assembly of Fig. 9.
Figure 11 is another embodiment of the electrode configuration of the pyroelectric sensor of Fig. 9.
Figure 12 is a further embodiment of the electrode configuration of the pyroelectric sensor of Fig. 9.
Figure 13 is a diagrammatical schematic view of an alternate calibration assembly.
Figure 14 is a diagrammatical perspective view of a heat detector.
Figure 15 is a diagrammatical schematic view of the heat detector of Figure 14.
Figure 16 is a diagrammatical longitudinal sectional view of an additional embodiment of a pyroelectric sensor.
Figure 17 is a diagrammatical longitudinal sectional view of a further embodiment of a pyroelectric sensor.

Description Of The Preferred Embodiments

[0014] Referring to the drawings wherein like numerals are used to identify the same or like parts, the electronic thermometer of the present invention is generally designated by the numeral 10. Referring, to Figures 1 and 2, thermometer 10 generally comprises a housing 12 forming an interior chamber 13, a barrel or wave guide 14 for directing infrared radiation into the chamber 13, a shutter assembly 16 for controlling the passage of infrared radiation through the barrel 14, a pyroelectric sensor assembly 18, an ambient temperature sensor 20, and an electronic circuit 22.

[0015] The housing 12 has an elongated lower end 24 which forms a pistol grip type handle of convenient size for one hand operation. The upper end 26 of the housing 12 forms the interior chamber 13 for mounting the pyroelectric sensor assembly 18 and the ambient temperature sensor 20, and provides a shield to exterior infrared radiation other than that received through the barrel 14.

[0016] The barrel 14 is mounted to the forward side 28 of housing 12 in alignment with the pyroelectric sensor 18 so as to direct or aim infrared radiation from the object 11 to be measured to the pyroelectric sensor mounted within the chamber 13. The barrel 14 is preferably made of metal and, though this is not shown in the drawings, is interconnected to the pyroelectric sensor 18 so as to be in thermal equilibrium therewith. Alternately to being made of metal, the interior of the barrel may be metallized.

[0017] Referring to Fig. 6, the barrel 14 is cylindrically shaped with a smooth, shiny interior surface 30 to facilitate transmission of infrared radiation from the open receiving end 32 to the pyroelectric sensor 18 and to provide a low emissivity to reduce error generated by secondary radiation from the barrel 14 in the event the barrel temperature differs somewhat from the temperature of the pyroelectric sensor 18. The overall length of barrel 14 determines the angle of view A as shown in Fig. 6 and for most medical applications, the length of the barrel is preferably in the range of 2-10 centimeters.

[0018] Preferably, the outer surface 34 of the barrel 14 is thermally isolated from ambient heat sources such as the human body by a protective thermoisolator coating 36. An acceptable thermoisolator coating is plastic, e.g., a plastic made from a phenolic resin. The exterior surface of the protective coating 36 is shiny to reflect outside heat. As shown in phantom line in Figure 6, a removable disposable protective cover 38 may be utilized in certain applications to prevent the barrel surface from contacting the object to be measured, e.g., to prevent contamination. The cover 38 has a low thermoconductivity and an acceptable material is a polyethylene type material.

[0019] The pyroelectric sensor assembly 18 is mounted within the chamber 13 and, as shown in Figure 2, is positioned in alignment with the barrel 14 so as to receive the infrared radiation passing through the barrel 14. Referring to Figure 3, the pyroelectric sensor assembly 18 comprises a base 40 forming an open-ended interior recess 42 for mounting a pyroelectric film 44 to receive the infrared radiation from the barrel 14. The pyroelectric film 44 is clamped between an outwardly disposed peripheral clamp 46 and an inwardly disposed peripheral contact ring 48. The contact ring 48 is securely mounted within the recess 42 in spaced disposition to

the base 40. An insulating insert spacer 50 electrically insulates the contact ring 48 from the base 40 and, as shown in Fig. 3, the insert 50 cooperatively engages the interior end of the contact ring 48 so as to maintain the contact ring in spaced disposition relative to the base 40.

[0020] In the illustrated embodiment, the pyroelectric film is an ultra thin foil of pyroelectric material such as polyvinylidene fluoride (PVDF). If electrically polarized, such a film exhibits a pyroelectric effect in that it is able to generate an electrical charge in response to a change of its temperature produced by the receipt of infrared radiation. Other configurations and materials such as those generally disclosed in Smith et al, U.S. Patent 4,379,971 and Cohen et al, U.S. Patent 3,809,920 may also be utilized. In the illustrated embodiment, polyvinylidene fluoride is a preferable material since it is sensitive to minute and rapid temperature changes in response to the infrared radiation utilized herein and is relatively economical.

[0021] Referring to Fig. 4, the pyroelectric film 44 may be of varying thicknesses ranging from 5 to 100 microns with the thickness being determined by the sensitivity and speed response desired for a particular application. A pair of planar electrodes 52, 54 are fixed on opposite sides of the pyroelectric film 44 with the electrode 52 facing outwardly from the recess 42 to first receive the infrared radiation from the barrel 14. In the illustrated embodiment, the outer electrode 52 is black to provide high emissivity and absorption of infrared radiation and the inner electrode 54 is nontransparent and highly reflective of infrared radiation. Alternately, the outer electrode 52 may be transparent to far infrared radiation and the inner electrode 54 may be reflective to provide a greater speed response and sensitivity.

[0022] In assembly, the base 40 and the clamp 46 are electrically connected to provide shielding for the pyroelectric film 44. The base 40 and the outer electrode 52 are connected to ground by the ground lead 56. The inner electrode 54 is electrically connected to the lead wire 58 through the contact ring 48. The lead wires 56, 58 connect the pyroelectric sensor assembly 18 to the electronic circuit 22. The pyroelectric film 44 is polarized during the manufacturing process so that the polarity of the signal generated in response to the reception of infrared radiation is compatible with the electronic circuitry being utilized. In the illustrated embodiment, the pyroelectric film is appropriately polarized so that the inner electrode generates a negative signal in response to a positive temperature change. In operation, the pyroelectric sensor 18 senses temperature change and generates an electrical signal indicative thereof.

[0023] In practice, it has been found that pyroelectric sensor assemblies 18 employing pre-polarized pyroelectric films 44 are substantial superior in terms of cost and ease of manufacture to prior art infrared sensors employing, for example, charged polymer films, thermocouples, thermopiles, or the like. Specifically, in comparison to the prior art sensors, film 44 has a relatively large area, e.g., on the order of 1 cm^2, and is sensitive to infrared radiation impinging on essentially any part of that area. Accordingly, the infrared thermometers of the present invention do not require systems for focusing infrared radiation on the sensor, such as, focusing tubes, parabolic mirrors, lenses, or the like. This makes for a significantly simpler device, which in turn, lowers the overall cost of the device and makes the device easier to manufacture.

[0024] The ambient temperature sensor 20 is mounted within the interior chamber 13 in thermal equilibrium with the pyroelectric sensor 18, the barrel 14, and the shutter element 66 so as to sense or monitor the internal temperature of the housing 12. The ambient temperature sensor 20 senses the internal temperature of the housing 12 and generates an electrical signal proportional thereto which is applied to the electronic circuit 22 through the connector 64. Acceptable temperature transducers that may be utilized for such ambient temperature sensing include thermistors, thermopiles, semiconductors, etc. Importantly, the ambient temperature sensor may be relatively slow-acting as contrasted to the fast-acting pyroelectric sensor and need only have a response time sufficient to track the changes of the internal ambient temperature of the chamber 13.

[0025] The exposure of the pyroelectric film 44 to infrared radiation directed through the barrel 14 is controlled by the shutter assembly 16. The shutter assembly 16 comprises a shutter 66, a shutter control mechanism 68, and a manually actuated pushbutton 70. The shutter 66 is operationally mounted at the inner end 33 of the barrel 14 so as to be actuable between a normally closed position closing off the transmission of infrared energy from the barrel 14 to the pyroelectric sensor 18 and an open position permitting infrared energy to pass from the barrel 14 to the pyroelectric sensor 18.

[0026] The shutter control mechanism 68 is of conventional design providing a high shutter opening speed in the range of 5-25 milliseconds. Acceptable conventional mechanisms include a mechanical trigger assembly, a solenoid actuated means, a stepper motor assembly, etc. The shutter 66 is actuated to an open position by depression of the pushbutton 70 and remains in the open position a sufficient time to permit the pyroelectric sensor 18 to generate the electrical signal responsive to shutter opening as explained hereinafter. The shutter 66 is returned to its normally closed position after approximately 200 milliseconds. A mechanical timing gear is utilized to control the duration of the shutter 66 in the open position. Alternately, the timing gear may be electro-mechanical.

[0027] The shutter control mechanism 68 includes noise supression elements and shock absorbers to reduce acoustical noise and other mechanical forces during the shutter opening operation to control the accuracy of the responsive electrical signal generated by the pyroelectric sensor 18. Since the pyroelectric film 44 has piezoelectric properties, excessive acoustical noise or

mechanical force can produce detrimental error and noise in the electrical signal generated by the pyroelectric film 44 in response to temperature changes.

[0028] The shutter 66 is configured to have a low thermal conductivity from its outer surface 72 to its inner surface 74 in order to prevent the shutter from becoming an extrinsically dependent secondary source of radiation to the pyroelectric film 44. Both the inner and outer surfaces of shutter 66 are reflective in nature in order to reduce emissivity and heating from external sources. The shutter 66 is also mounted within the chamber 13 so as to be in thermal equilibrium with the pyroelectric sensor 18.

[0029] The electronic circuit 22 includes an amplifier circuit 60, a microprocessor or microcontroller 76, a shutter sensor switch 77 and a digital visual display device 78. The microprocessor 76 is interconnected to the ambient temperature sensor 20, the amplifier circuit 60 and the shutter sensor switch 77 to receive electrical input signals indicative of the internal ambient temperature of the thermometer housing 12, the actuation of shutter assembly 16, and the temperature differential between the pyroelectric sensor 18 and the object to be measured. The microprocessor 76 is of conventional design having suitable data and program memory and being programmed to process the electrical signal from the ambient temperature sensor 20 and the amplified electrical signal from the pyroelectric sensor 18 in accordance with the following description to calculate the absolute temperature of the body 11 to be measured. Based upon the calculated temperature of the subject 11, the microprocessor 76 generates a control signal to drive the display device 78 to visually indicate the calculated temperature.

[0030] More specifically, the amplitude of the electrical signal generated by the pyroelectric sensor is a nonlinear function of the difference between the temperature of the subject to be measured and the temperature of the sensor prior to exposure to the radiation emitted by the subject, i.e., the difference between the temperature of the subject and the ambient temperature of the thermometer. The general characteristics of this function can be described in terms of the Stefan-Boltzman equation for radiation and the Fourier equation for heat transfer. Both these equations, however, are highly nonlinear. Moreover, there exists no known analytical relationship between the amount of radiation striking a pyroelectric film, such as a PVDF film, and the voltage produced by the film.

[0031] In accordance with the present invention, it has now been found that notwithstanding these non-linearities and the lack of an analytical relationship for film output, the temperature of a subject can be accurately determined using pyroelectric films by means of the following procedure. First, the voltage V_{lr} produced by the film in response to radiation from the subject is approximated by the formula:

$$V_{lr} = f(T_a)(T_s^4 - T_a^4) \quad (1)$$

where T_s is the absolute temperature of the subject, T_a is the absolute ambient temperature determined from ambient temperature sensor 20, and $f(T_a)$ is a polynomial in T_a, namely,

$$f(T_a) = a_0 + a_1T_a + a_2T_a^2 + a_3T_a^3 + \ldots$$

[0032] Next, the coefficients a_0, a_1, a_2, a_3, etc. are determined for the particular sensor design and type of film being used by measuring V_{lr} for a series of known T_s's and T_a's, substituting those values into equation 1, and solving the resulting set of simultaneous equations for the polynomial coefficients. In practice, it has been found that for measuring body temperatures, sufficient accuracy can be achieved through the use of only three terms, i.e., through the use of a second order polynomial in T_a. For other applications, where greater accuracy may be required, more terms can be used if desired.

[0033] Finally, the temperature of a subject whose temperature is to be measured is determined by microprocessor 76 by evaluating the following equation using V_{lr} from pyroelectric sensor 18, T_a as derived from ambient sensor 20, and the polynomial coefficients a_0, a_1, a_2, a_3, etc. determined as described above:

$$T_s = (V_{lr}/f(T_a) + T_a^4)^{1/4}$$

[0034] The microprocessor 76 is thus adapted to provide the necessary analysis of the electrical signals from the ambient temperature sensor and the pyroelectric sensor, including appropriate scaling, correction, etc., to calculate absolute temperature. The calculated temperature is processed into a digital format for storage in memory and for generating a control signal to drive the digital display. In practice, using the above procedure and a PVDF film, it has been found that body temperatures can be reliable measured with the thermometer of the present invention to within approximately 0.1°C.

[0035] Referring to Figure 8, a graphic representation of V_{lr} is shown for an exemplary temperature measurement of an object having a temperature greater than the internal ambient temperature of the thermometer. As indicated, the pyroelectric sensor signal (V_{lr}) quickly reaches its maximum or peak value after the opening of the shutter and starts to slowly decay. The rate of decay of the signal is dependent upon various physical parameters of the pyroelectric film 44 such as thickness, emissivity, thermal time constant, etc. In the illustrated embodiment, the microprocessor 76 is responsive only to the peak absolute value of the pyroelectric sensor signal so that the actual period the shutter remains open is not critical as long as the shutter is open long enough to allow the signal to reach its peak absolute value. Where

the subject being measured has a temperature greater than the ambient temperature of the thermometer, the peak absolute value of the voltage signal is a maximum voltage as shown in Figure 8, whereas the peak absolute value would be a minimum voltage if the subject had a temperature lower than the ambient temperature of the thermometer. After the microprocessor 76 determines the peak value, the measurement is complete and the microprocessor becomes insensitive or nonresponsive to further input signals from the pyroelectric sensor.

[0036] Alternatively, the microprocessor 76 may be programmed to calculate the absolute temperature of the subject by integration of V_{ir} over a predetermined fixed time frame t_0 according to the following equation:

$$e = k_i \int_0^{t_0} V_{ir}\, dt$$

where, k_I = a calibration factor in I/sec.

[0037] The integration method of measurement calculation is more resistant against high frequency noise such as may be picked up by the pyroelectric sensor and is particularly advantageous where the temperature of the subject to be measured is relatively close to the internal temperature of the thermometer.

[0038] It is important to note that for both the peak absolute value approach and the integration approach, the signal being measured is the transient response of the pyroelectric film to the infrared radiation reaching the film during the time when shutter 66 is open, that is, in accordance with the present invention, the transient response of the film to a single pulse of infrared radiation is all that is measured. This is in direct contrast to prior art infrared thermometers which either measured the steady state response of the sensor or employed a chopper to break up the incoming infrared radiation into a series of pulses and then averaged the response of the sensor to those pulses. By measuring the transient response, the thermometer of the present invention has a faster response time than prior art thermometers which had to wait until a steady state was achieved; by using only one pulse, the present invention avoids the need for both a chopper and averaging circuitry, thus allowing for the production of a less complicated and less expensive device which is easier to manufacture. Moreover, notwithstanding the fact that only one pulse of infrared radiation is measured, the thermometer of the present invention has been surprisingly found to consistently and accurately measure body temperatures.

[0039] Referring to Fig. 7, the amplifier circuit 60 of the present invention is shown in detail. In the illustrated embodiment, the pyroelectric sensor 18 generates a negative signal in response to positive temperature change. The pyroelectric sensor signal is applied via lead 58 to the negative input terminal of the amplifier 61 and an internally generated reference voltage (V_{ref}) is applied to the positive input terminal. Preferably, the amplifier has a JFET or CMOS input stage and is a current-to-voltage converter whose input impedance is dependent upon the bias resistor 80 and the ratio of resistors 82, 84. Capacitor 86 provides negative feedback to maintain the stability of the amplifier and reduce high-frequency noise. Capacitor 88 blocks out low frequency drifts and offset voltages in the voltage output signal V_{out} which is applied to the input of microprocessor 76 by lead 87. The analog switch 90 is normally in a closed position prior to actuation of the shutter assembly 16 so that the amplifier output voltage is equal to the internally generated reference voltage. The analog switch 90 is connected by lead 92 to the shutter actuation sensor switch 77 which generates an indicator signal upon actuation of the shutter assembly 16 by the pushbutton 70. Upon actuation of the shutter assembly, the indicator signal generated by the sensor switch 77 causes the analog switch 90 to open and the voltage output V_{out} is then the amplified signal V_{ir} from the pyroelectric sensor 18 which changes rapidly in response to the infrared radiation from the subject to be measured.

[0040] In operation, the outer end of the barrel 14 is positioned in spaced disposition adjacent the subject 11 to be measured. Upon actuation of the pushbutton 70 and the opening of the shutter 66, infrared radiation from the subject 11 is directed along the barrel 14 to the pyroelectric film 44 of the pyroelectric sensor 18. The pyroelectric film 44 generates an electrical signal which is a function of the change in temperature caused by the infrared radiation from the subject 11. Based upon the ambient temperature of the interior of the thermometer as sensed by the ambient sensor 20 and the temperature change of the pyroelectric sensor assembly caused by the infrared radiation reaching the sensor from the subject, the temperature of the subject is calculated.by the microprocessor 76 and displayed on the digital display 78. The response time of the thermometer is relatively fast being in the order of 0.25 seconds. As can be seen from the foregoing, a fast temperature reading is obtained with a noncontacting electronic thermometer which is easy to use and economical to manufacture.

[0041] Another embodiment of a pyroelectric sensor assembly is shown in Figure 5 being generally designated by the numeral 19. The pyroelectric sensor 19 comprises a contact ring or insert 48 integrally formed with a contact pin 58 which extends through the insulating insert 50. The pyroelectric film 44 is clamped between the contact ring 48 and the clamp 46 with the clamp 46 being held in place by the rolled edges 41 of the base 40. The outer electrode 52 is connected to ground through the clamp 46 and the base 40 while the inner electrode 54 is connectable to the amplifier circuit 22 through the contact ring 48 and the contact pin 58. The remaining elements function similarly to the embodiment of Figure 3 and need not be described in detail.

The configuration of Figure 5 is particularly suited for economical high-volume manufacture and also facilitates the assembly of the thermometer 10 because of its compatibility with automated manufacturing processes.

[0042] Additional embodiments of the pyroelectric sensor assembly are shown in Figures 16-17. In Figure 16, polymer film 44, having electrodes 52 and 54 on its front and rear faces, is mounted inside nonconductive housing or support 150. The film can be mounted to the housing in various ways, such as, through the use of glue, heat welding, or the like. To protect the film, the front face of the sensor can include a cover 163 made of material which is transparent to far infra-red radiation, such as, polyethylene. To equalize the pressure on both sides of the film, housing 150 preferably includes an opening 160 in its rear wall leading into the cavity formed by the film and the walls of the housing.

[0043] Two contacts 161 and 162 are molded into housing 150. Contact 162 is connected to front electrode 52, and contact 161 is connected to rear electrode 54. These connections can be made by physical contact or via a conductive media, such as, a conductive epoxy, e.g., Rgon.

[0044] Figure 17 shows a modified version of the sensor assembly of Figure 16 wherein ambient sensor 20 is mounted in the same housing 164 as polymer film 44. In particular, ambient sensor 20 is mounted in the cavity formed by film 44 and the walls of housing 164. In this way, better thermal coupling between the film and the ambient temperature sensor is achieved.

[0045] Referring to Figure 9, an optional calibration circuit 94 is shown for calibrating the pyroelectric sensor signal to compensate for possible variations due to material aging, temperature drifts, instability of electronic components, etc. which may produce unacceptable error in the temperature measurement. The pyroelectric film 44 has piezoelectric properties which are necessarily subjected to the same environmental factors (such as material aging, temperature, etc.) as its pyroelectric properties. Consequently, calibration may be attained by an electrical calibration, i.e., piezo-calibration, as opposed to a thermal calibration, i.e., pyro-calibration. The application of a predetermined reference signal to the piezoelectric-pyroelectric film will generate a mechanical stress or deflection at one portion of the film and that stress may be sensed in the other portion of the film since it generates a responsive signal. Thus, calibration is attained through application of a predetermined electrical calibration signal to the pyroelectric film prior to each temperature measurement calculation to generate a responsive signal. The responsive signal is utilized by the microprocessor as a correction factor in the temperature calculations.

[0046] Referring to Figure 9, the outer planar electrode 96 on the outwardly facing surface of the pyroelectric film 44 is comprised of two separate spaced electrode segments 98, 100. The electrode segment 100 is connected to amplifier circuit 60. The electrode segment 98 is connected to switch 102 which alternately interconnects the electrode segment 98 to either the amplifier circuit 60 or to an excitation signal circuit 104.

[0047] The excitation circuit 104 is of conventional design for producing a predetermined electrical calibration signal 106 adapted to excite the piezoelectric film to produce a mechanical stress and, in turn, a responsive electrical signal 108 (Figure 10). The value of the responsive electrical signal at the time of assembly and initial calibration of the thermometer 10 will constitute a predetermined standard and is stored in memory. The switch 102 and the excitation signal circuit 104 are controlled by the microprocessor 76 and, upon command from the microprocessor 76 during the calibration operation, the excitation signal circuit generates a predetermined electrical calibration signal 106.

[0048] The calibration operation is performed with the shutter 66 in a closed position as diagrammatically shown in Figure 9. Prior to opening the shutter 66, the switch 102 interconnects the electrode segment 98 to the signal excitation circuit 104 and the predetermined electrical signal 106 is applied to the electrode 98. Due to the piezoelectric properties of the pyroelectric film 44, this causes a mechanical stress and, in turn, the mechanical stress causes the piezoelectric film 44 to generate a responsive electrical signal 108 in electrode 96 which is conducted to the amplifier circuit 60 via the electrode segment 100. Since the mechanical stress calibration signal is a predetermined value, deviation in the response signal 108 is indicative of changes in the pyroelectric sensor 18 and the degree of deviation from the predetermined standard provides the necessary calibration information for appropriate correction by the microprocessor 76. Immediately following the calibration operation, the switch 102 interconnects the electrode segment 98 to the amplifier circuit 60 which thereby doubles the infrared sensitivity area of the film and the temperature measurement operation is performed as previously described relative to the embodiment of Figs. 1 and 2.

[0049] Preferably, calibration is performed immediately prior to each measurement operation to ensure reliable and accurate absolute temperature measurement. Any changes in the pyroelectric properties of the pyroelectric film 44 due to aging, environment, etc. will be automatically compensated for by the microprocessor 76 in calculating the absolute temperature of the subject.

[0050] Referring to Figs. 11 and 12, alternate embodiments of the planar electrode segments 98, 100 are shown. In Fig. 11, the electrode segments 98, 100 are interdigitized on the inward facing surface of the pyroelectric film 44. In Fig. 12, the electrode segment 98 is coaxial to the electrode segment 100 and the electrode segment 98 may be permanently connected to the excitation network 104 thereby eliminating the necessity for switch 102. However, the thermal sensitive area of

the pyroelectric film 44 will be limited to the electrode segment 100.

[0051] Referring to Fig. 13, an alternate configuration for calibrating the pyroelectric sensor assembly 18 is shown. In this configuration, a heating element 108 is controlled by a controller 110 to provide a predetermined stable infrared radiation level upon command from the microprocessor 76.

[0052] The inner surface of the shutter 66 has a reflective plate 114 aligned with the heating element 108 and the pyroelectric sensor 18 so as to reflect the infrared beam 112 from the heating element 108 to the pyroelectric sensor assembly. Necessarily, the generated infrared radiation beam 112 is stable under operating conditions. The electrical signal generated by the pyroelectric sensor in response to the infrared beam 112 provides a reference signal to the microprocessor 76 to enable it to calculate the amount of correction required in the subsequent temperature measurement calculation. Again, the calibration operation is performed with the shutter 66 in a closed position and preferably the calibration operation is performed prior to each temperature measurement operation.

[0053] Alternately, the microprocessor 76 may be provided with a predetermined table of error correction data based upon the known sources of error and changes in the responsive characteristics of the pyroelectric film. The microprocessor is programmed to adjust the calculated absolute temperature in accordance with the error correction data.

[0054] As can be seen, a new and improved noncontacting electronic thermometer has been provided which is accurate, reliable, and economical to manufacture. In operation, the electronic thermometer is compact and easy to use and measures absolute temperature of an object virtually instantaneously.

[0055] Referring to Figures 14 and 15, a further embodiment of the present invention is shown in the nature of a heat differential detector 130 for the detection of warm spots on a surface. The detection of warm spots is often desirable to locate bone fractures, tissue inflammation, etc. The heat detector 130 generally comprises a housing, a barrel 14, a pyroelectric sensor assembly 18 having a pyroelectric film 44, an electric circuit 22 and an indicator light 116.

[0056] The barrel 14 and pyroelectric sensor 18 function as previously described with respect to the embodiment of Figure 1. The electronic circuit 22 generally comprises an amplifier 60, a comparator 118, and an indicator circuit 120. The output of the amplifier 60 is connected through capacitor 122 to the comparator 118. The threshold point of the comparator may be varied by the potentiometer 124. A pushbutton reset switch 126 permits discharge of the capacitor 122 to ground. The indicator circuit 120 is connected to the comparator 118 and drives the indicator light 116 or any other acceptable indicator such as an audio tone generator, etc.

[0057] In operation, the capacitor 122 is discharged by momentary actuation of the switch 126 prior to beginning the sensing operation. To sense or detect a warm spot, as for example the warm spot 128 on skin surface 131 as shown in Figure 14, the heat detector is positioned so that the open receiving end 32 of the barrel 14 is adjacent the surface 131. The heat detector 130 is then moved along the surface at approximately a constant race of speed. When the warm spot 128 enters the field of view of the barrel 14, the increase in infrared radiation from the warm spot 128 causes the pyroelectric sensor 18 to generate an indicative electrical signal. The amplified electrical signal 1 is applied to the comparator 118 and if the electrical signal exceeds the set threshold value of the comparator, the indicator circuit 120 will be actuated to drive the indicator light 116. The threshold point of the comparator my be varied depending on the particular heat sensing application.

[0058] Accordingly, a heat detector is provided which is convenient and easy to use and which is economical to manufacture.

[0059] As will be apparent to persons skilled in the art, various modifications and adaptions of the structure above-described will become readily apparent without departure from the scope of the invention, the scope of which is defined in the appended claims.

Claims

1. A thermometer comprising:

a housing (12);
a pyroelectric (18) sensor carried within said housing (12) and responsive to infrared radiation for generating an electrical signal which exhibits a transient response upon receipt of said radiation;
directing means (14), carried by said housing (12), in optical alignment with said sensor (18), for directing infrared radiation from an object (11), the actual temperature of which is to be measured, to impinge upon said sensor (18), said directing means (14) including an elongate wave guide (14) of predetermined length having an outer end (32) to receive infrared radiation from the object to be measured and an inner end (33) in operative alignment with the sensor (18), said waveguide (14) being interconnected to said sensor (18) so as to be in thermal equilibrium therewith and having a smooth and shiny interior surface (30) of low emissivity to facilitate transmission of infrared radiation.
enabling means (16), carried by said housing (12), for enabling response of said sensor (18) to said radiation;
and electrical means (22) carried by said housing (12) and responsive to said transient re-

sponse of said signal for processing said signal to develop an indication of the actual temperature of said object (11).

2. A thermometer as defined in claim 1 in which said directing means (14) is in itself of low infrared radiation emissivity to reduce its contribution to radiation directed to said sensor (18).

3. A thermometer as defined in claim 1 or 2, in which said directing means (14) exhibits substantial thermal isolation from ambient sources of heat external to said directing means (14).

4. A thermometer as defined in any preceding claim in which said sensor (18) is a pyroelectric element (44) sandwiched between a first electrode (52) disposed in use to face said object (11) and a second electrode (54) on the opposed surface of said element, said first electrode (52) exhibiting the characteristic of high emissivity and absorption of said infrared radiation.

5. A thermometer as defined in any of claims 1 to 3 in which said sensor (18) is a pyroelectric element (44) sandwiched between a first electrode (52) disposed in use to face said object (11) and a second electrode (54) on the opposed surface of said element, and in which said second electrode (54) is nontransparent to and highly reflective of said infrared radiation.

6. A thermometer as defined in any of claims 1 to 3 in which said sensor (18) is a pyroelectric element (44) sandwiched between a first electrode (52) disposed in use to face said object (11) and a second electrode (54) on the opposed surface of said element, and in which said first electrode (52) is transparent to far infrared radiation and said second electrode (54) is substantially reflective thereto.

7. A thermometer as defined in any preceding claim in which said directing means (14) is arranged to deliver infrared radiation from said object within a predetermined angle of view and to effect impingement of said radiation upon said sensor (18) over a relatively wide area.

8. A thermometer as defined in any preceding claim in which said electrical means (22) automatically becomes insensitive to further input signals from said sensor (18) after receipt of said transient response.

9. A thermometer as defined in any preceding claim in which said electrical means (22) includes means for calculating the absolute temperature of said object by integration of the level of said response over a fixed time frame.

10. A thermometer as defined in any preceding claim in which said sensor (18) exhibits said transient in response to a single pulse of said radiation, and in which said electrical means (22) responds only to said single pulse.

11. A thermometer as defined in any preceding claim in which said sensor (18) is mounted within said housing (12), and in which said housing (12) includes means (150,160)to equalize the pressure on both sides of said sensor (18).

12. A thermometer as defined in any preceding claim in which a heating element (108) is carried by said housing (12) in a position to yield heat to said sensor (18) and provide a calibrating stable infrared level imposed upon said sensor;

and in which said electrical means (22) responds to said sensor (18) as heated by said heating element (108).

13. A thermometer as defined in any preceding claim in which said electrical means (22) includes a microprocessor (76) having an electronic memory which contains a predetermined table of correction data in accordance with known possible sources of error and changes in responsive characteristics of said sensor (18), with said electrical means (22) programmed to adjust the calculated absolute temperature of said object (11) in accordance with said correction data.

14. A thermometer as defined in any preceding claim wherein said directing means (14) includes means (36) on said outer surface (34) for thermally isolating said outer surface (34) from external ambient heat sources.

15. A thermometer as defined in claim 14 wherein said means (36) for thermally isolating comprises a thermoisolator coating on said outer surface.

16. A thermometer as defined in any preceding claim in which said sensor (18) is responsive to a predetermined electrical calibration signal;

in which said electrical means (22) includes means for applying to said sensor said electrical calibration signal;

and in which said electrical means (22) responds to the sensor output from said calibration signal by correcting calculation of said actual temperature.

17. A thermometer as defined in claim 16 in which said electrical means (22) is arranged to increase the sensitivity area of said sensor (18) to said radiation by a predetermined amount following response to said calibration signal.

18. A thermometer as defined in claim 16 or 17 in which said sensor (18) is a pyroelectric element (44) sandwiched between a first electrode (52) disposed to face said object (11) and a second electrode (54) on the opposed surface of said element, and in which one of said electrodes (52,54) comprises two separate and spaced electrode segments (98,100) wherein said segments are included in said applying means.

19. A thermometer as defined in claim 18 which further includes means (102) for interconnecting said segments (98,100) prior to said response of said sensor (18) to said radiation.

20. A thermometer as defined in any preceding claim which further includes means (20) carried by said housing (12) and responsive to the ambient temperature of said sensor (18) prior to said initial receipt of said radiation for generating another electrical signal representative of said ambient temperature, and in which said electrical means (22) processes said other electrical signal to calculate actual temperature of said object.

21. A thermometer as defined in claim 20 in which said housing defines an interior chamber, and in which said ambient temperature means (20) also is disposed within said chamber in thermal equilibrium with said sensor (18).

22. A thermometer as defined in claim 20 or 21 in which said ambient temperature means (20) exhibits its electrical signal in slow response as compared with the response of said sensor (18) to said radiation.

23. A thermometer as defined in claim 20 or 21 or 22 in which said ambient temperature means (20) is mounted within a cavity defined within the interior of a housing (164) by the sensor (18).

24. A thermometer as defined in any of claims 20 to 23 wherein the temperature of the object to be measured by said electrical means (22) is calculated using the equation:

$$T_s = [V_{ir}/f(T_a)+T_a^{\,4}]^{1/4},$$

where T_s is the absolute temperature of the object to be measured, V_{ir} is the first electrical signal generated by said sensor, T_a is the absolute ambient temperature determined by said electrical means from said other electrical signal generated by said ambient temperature means and $f(T_a)$ is a polynomial in T_a given by equation:

$$f(T_a) = a_o+a_1T_a+a_2T_a^{\,2}+a_3T_a+...$$

where the polynomial coefficients a_o, a_1, a_2, a_3 ... are determined by exposing said sensor at a known ambient temperature to objects having known temperatures.

25. A thermometer as defined in claim 24 wherein the signal V_{ir} is approximated by using the formula:

$$V_{ir} = f(T_a)(T_s^{\,4} - T_a^{\,4}).$$

26. A thermometer as defined in any preceding claim in which said enabling means (16) includes:

a shutter (66) carried by said housing (12) and movable between a first position blocking transmission of said radiation from said directing means (14) to said sensor (18) and a second position which enables passage of said radiation to said sensor;
means (68) for moving said shutter (66) between said first and second positions;
and means (70) for controlling movement of said shutter (66) to enable response of said sensor (18) to said radiation to exhibit said transient response upon receipt of said radiation.

27. A thermometer as defined in claim 26 in which said controlling means (70) enables movement of said shutter (66) to said first position substantially upon termination of said transient response.

28. A thermometer as defined in claim 26 or 27 in which said controlling means (68) includes means for suppressing and absorbing noise and shock developed upon the movement of said shutter (66) between said first and second positions.

29. A thermometer as defined in claim 26 or 27 or 28 in which said housing (12) includes an interior chamber (13) in which said sensor (18) is contained, and in which said shutter (66) is mounted as to be in thermal equilibrium with said sensor (18).

30. A thermometer as defined in any of claims 26 to 29 which includes means for supplying said electrical means (22) with input signals indicative of the ambient temperature of the said sensor (18), and in which the actuation of said shutter (66) enables the calculation of the temperature differential between said sensor (18) and said object.

31. A thermometer as defined in any of claims 26 to 30 in which said electrical means (22) includes means for responding to actuation of said shutter (66) in

order to provide an indication signal that causes said transient response to be measured.

32. A thermometer as defined in any of claims 26 to 31 in which said shutter (66) exhibits a low thermal conductivity between a first surface (72) which faces said directing means (14) and a second surface (74) which faces said sensor (18).

33. A thermometer as defined in claim 32 in which both of said surfaces (72,74) of said shutter (66) are reflective to the said radiation.

34. A method for measuring the temperature of an object with a thermometer having a housing (12), carrying a pyroelectric sensor (18) within the housing so as to be responsive to infrared radiation for generating an electrical signal which exhibits a transient response upon receipt of said radiation from the object along an elongated wave guide having a smooth and shiny interior surface of low emissivity to facilitate transmission of infrared radiation, and an outersurface, being of predetermined length for receiving the said infrared radiation from the object within the guide through an outer end (32) thereof, ensuring the guide is in operative alignment with the sensor (18) arranging for the waveguide to be connected with the sensor so that the sensor is in thermal equilibrium therewith, utilising enabling means carried by the housing to enable response of said sensor (18) to said radiation, and enabling electrical means (22) carried by said housing and being responsive to said transient response of said signal so as to process said signal to develop an indication of the actual temperature of said object.

35. The method of claim 34 comprising calculating the temperature of the object to be measured using the equation:

$$T_s = [V_{Ir}/f(T_a)+T_a^4]^{¼},$$

where T_s is the absolute temperature of the object to be measured, V_{Ir} is the first electrical signal generated by said pyroelectric sensor (18), T_a is the absolute ambient temperature determined from said second electrical signal, and $f(T_a)$ is a polynomial in T_a given by the equation:

$$f(T_a) = a_o+a_1T_a+a_2T_a^2+a_3T_a+...$$

where the polynomial coefficients a_o, a_1, a_2, a_3 ... are determined by exposing said pyroelectric sensor at a known ambient temperature to objects having known temperatures.

36. The method of claim 35 comprising approximising the signal V_{Ir} using the formula:

$$V_{Ir} = f(T_a)(T_s^4 - T_a^4).$$

37. The method of any of claims 34 to 36 comprising calibrating the sensitivity of said pyroelectric sensor (18) prior to selectively exposing said pyroelectric sensor to infrared radiation from the object to be measured.

38. The method of claim 37 comprising adapting the said pyroelectric sensor (18) to exhibit piezoelectric properties and calibrating the sensitivity of said pyroelectric sensor comprising:

applying a predetermined calibration signal to said pyroelectric sensor so as to cause said pyroelectric sensor to generate a responsive electrical calibration signal;
and correcting said first electrical signal generated by said pyroelectric sensor based upon said responsive electrical calibration signal and a predetermined standard value.

39. The method of claim 38 wherein calibrating the sensitivity of said pyroelectric sensor (18) comprises:

applying a predetermined level of infrared radiation to said pyroelectric sensor so as to cause said pyroelectric sensor to generate a responsive electrical calibration signal;
and correcting said first electrical signal generated by said pyroelectric sensor based upon said responsive electrical calibration signal and a predetermined standard value.

Patentansprüche

1. Thermometer, aufweisend:

ein Gehäuse (12),
einen pyroelektrischen Sensor (18), der im Gehäuse (12) gehalten ist und auf Infrarotstrahlung anspricht, um ein elektrisches Signal zu erzeugen, das aufgrund eines Empfangs der genannten Strahlung eine Übergangs-Antwort zeigt,
eine Richtungseinrichtung (14), die von dem Gehäuse (12) gehalten wird und auf den Sensor (18) optisch ausgerichtet ist, um Infrarotstrahlung von einem Objekt (11) auszurichten, dessen tatsächliche Temperatur gemessen werden soll, so daß jene auf den Sensor (18) einfällt, wobei die Richteinrichtung (14) einen länglichen Wellenleiter (14) vorbestimmer Län-

ge mit einem äußeren Ende (32) zum Empfang von Infrarotstrahlung von dem zu messenden Objekt und einem inneren Ende (33) in betriebsmäßiger Ausrichtung zu dem Sensor (18), wobei der Wellenleiter (14) mit dem Sensor (18) so verbunden ist, daß er sich mit diesem im thermischen Gleichgewicht befindet, und eine gleichmäßige glänzende Innenfläche (30) niedriger Abstrahlung aufweist, um die Übertragung von Infrarotstrahlung zu erleichtern,
eine Freigabeeinrichtung (16), die von dem Gehäuse (12) gehalten wird, um eine Antwort des Sensors (18) auf die Strahlung zu bewirken, und
eine elektrische Einrichtung (22), die von dem Gehäuse (12) gehalten wird und auf die Übergangs-Antwort des genannten Signals anspricht, um das Signal zu verarbeiten und eine Angabe der tatsächlichen Temperatur des Objekts (11) zu erzeugen.

2. Thermometer nach Anspruch 1, wobei die Richteinrichtung (14) selbst eine geringe Infrarotstrahlungs-Abstrahlung aufweist, um ihren Beitrag zur auf den Sensor (18) gerichteten Strahlung zu reduzieren.

3. Thermometer nach Anspruch 1 oder 2, wobei die Richteinrichtung (14) eine wesentliche thermische Isolation von Umgebungs-Wärmequellen aufweist, die sich außerhalb der Richteinrichtung (14) befinden.

4. Thermometer nach einem der vorhergehenden Ansprüche, wobei der Sensor (18) ein pyroelektrisches Element (44) darstellt, das zwischen eine in Gebrauch dem Objekt (11) zugewandte erste Elektrode (52) und eine zweite Elektrode (54) auf der gegenüberliegenden Fläche des Elements gepackt ist, wobei die erste Elektrode (52) die Eigenschaft hoher Abstrahlung und Absorption der genannten Infrarotstrahlung aufweist.

5. Thermometer nach einem der Ansprüche 1 bis 3, wobei der Sensor (18) ein pyroelektrisches Element (44) ist, das zwischen eine im Gebrauch dem genannten Objekt (11) zuwandte erste Elektrode (52) und eine zweite Elektrode (54) auf der gegenüberliegenden Fläche des Elements gepackt ist, wobei die zweite Elektrode (54) gegenüber der Infrarotstrahlung opak und hochreflektiv ist.

6. Thermometer nach einem der Ansprüche 1 bis 3, wobei der. Sensor (18) ein pyroelektrisches Element (44) ist, das zwischen eine in Gebrauch dem genannten Objekt (11) zugewandte erste Elektrode (52) und eine zweite Elektrode (54) auf der gegenüberliegenden Fläche des Elements gepackt ist, wobei die erste Elektrode (52) gegenüber ferner Infrarotstrahlung transparent und die zweite Elektrode (54) im wesentlichen reflektiv demgegenüber ist.

7. Thermometer nach einem der vorhergehenden Ansprüche, wobei die Richteinrichtung (14) so eingerichtet ist, daß sie Infrarotstrahlung von dem Objekt innerhalb eines bestimmten Sichtwinkels abgibt und den Einfall der Strahlung auf den Sensor (18) über einen relativ weiten Bereich erlaubt.

8. Thermometer nach einem der vorhergehenden Ansprüche, wobei die elektrische Einrichtung (22) nach Empfang der Übergangs-Antwort automatisch gegenüber weiteren Eingangssignalen von dem Sensor (18) unempfindlich wird.

9. Thermometer nach einem der vorhergehenden Ansprüche, wobei die elektrische Einrichtung (22) eine Einrichtung zur Berechnung der absoluten Temperatur des Objekts durch Integration des Antwortpegels über einen festgelegten Zeitrahmen beinhaltet.

10. Thermometer nach einem der vorhergehenden Ansprüche, wobei der Sensor (18) den genannten Übergang in Antwort auf einen einzigen Impuls der genannten Strahlung zeigt und die elektrische Einrichtung (22) lediglich auf den genannten einen Impuls antwortet.

11. Thermometer nach einem der vorhergehenden Ansprüche, wobei der Sensor (18) innerhalb des Gehäuses (12) befestigt ist, und das Gehäuse (12) eine Einrichtung (150, 160) zum Ausgleich des Drucks auf beiden Seiten des Sensors (18) beinhaltet.

12. Thermometer nach einem der vorhergehenden Ansprüche, wobei von dem Gehäuse (12) ein Heizelement (108) in einer Position gehalten wird, so daß Wärme an den Sensor (18) abgegeben und ein stabiler Infrarotpegel zur Kalibrierung auf den Sensor gebracht wird, und
die elektrische Einrichtung (22) auf den von dem Heizelement (108) erwärmten Sensor (18) anspricht.

13. Thermometer nach einem der vorhergehenden Ansprüche, wobei die elektrische Einrichtung (22) einen Mikroprozessor (76) mit einem elektrischen Speicher aufweist, der eine vorbestimmte Tabelle von Korrekturdaten entsprechend bekannten möglichen Fehlerquellen und Änderungen im Ansprechverhalten des Sensors (18) enthält, und die elektrische Einrichtung (22) so programmiert ist, daß die berechnete absolute Temperatur des Objekts (11) entsprechend den Korrekturdaten eingestellt wird.

14. Thermometer nach einem der vorhergehenden Ansprüche, wobei die Richteinrichtung (14) eine Einrichtung (36) auf der äußeren Fläche (34) zum thermischen Isolieren der äußeren Fläche von äußeren Umgebungswärmequellen aufweist.

15. Thermometer nach Anspruch 14, wobei die genannte Einrichtung (36) zur thermischen Isolierung eine Wärmeisolierbeschichtung auf der äußeren Fläche aufweist.

16. Thermometer nach einem der vorhergehenden Ansprüche, wobei der Sensor (18) auf ein vorbestimmtes elektrisches Kalibrierungssignal anspricht,

die elektrische Einrichtung (22) eine Einrichtung zum Anlegen des elektrischen Kalibrierungssignals an den Sensor aufweist, und

die elektrische Einrichtung (22) auf die Sensorausgabe anspricht, indem die Berechnung der tatsächlichen Temperatur korrigiert wird.

17. Thermometer nach Anspruch 16, wobei die elektrische Einrichtung (22) eingerichtet ist, die Empfindlichkeitsfläche des Sensors (18) auf die Strahlung aufgrund eines Ansprechens auf das Kalibrierungssignal um einen vorbestimmten Betrag zu erhöhen.

18. Thermometer nach Anspruch 16 oder 17, wobei der Sensor (18) ein pyroelektrisches Element (44) darstellt, das zwischen eine dem Objekt (11) zugewandte erste Elektrode (52) und eine auf der gegenüberliegenden Fläche des Elements vorgesehenen zweite Elektrode (54) gepackt ist, und wobei eine der Elektroden (52, 54) zwei getrennte Elektrodensegmente (98, 100) mit Abstand voneinander aufweist, die in der genannten Anlegeinrichtung enthalten sind.

19. Thermometer nach Anspruch 18, mit einer Einrichtung (102) zur Verbindung der Segmente (98, 100) miteinander vor dem Ansprechen des Sensors (18) auf die genannte Strahlung.

20. Thermometer nach einem der vorhergehenden Ansprüche mit einer Einrichtung (20), die von dem Gehäuse (12) gehalten wird und auf die Umgebungstemperatur des Sensors (18) vor dem anfänglichen Empfang der genannten Strahlung anspricht, um ein anderes elektrisches Signal zu erzeugen, das die Umgebungstemperatur darstellt, und wobei die elektrische Einrichtung (22) das genannte andere Signal verarbeitet, um die tatsächliche Temperatur des Objekts zu berechnen.

21. Thermometer nach Anspruch 20, wobei das Gehäuse eine Innenkammer festlegt, und die genannte Umgebungstemperatureinrichtung (20) ebenfalls innerhalb der Kammer im thermischen Gleichgewicht mit dem Sensor (18) angeordnet ist.

22. Thermometer nach Anspruch 20 oder 21, wobei die Umgebungstemperatureinrichtung (20) ihr elektrisches Signal in einer langsamen Antwort im Vergleich zur Antwort des Sensors (18) auf die genannte Strahlung zeigt.

23. Thermometer nach Anspruch 20, 21 oder 22, wobei die Umgebungstemperatureinrichtung (20) innerhalb eines im Inneren des Gehäuses (164) durch den Sensor (18) festgelegten Hohlraums angebracht ist.

24. Thermometer nach einem der Ansprüche 20 bis 23, wobei die Temperatur des zu messenden Objekts von der elektrischen Einrichtung (22) unter Verwendung folgender Formel berechnet wird:

$$T_s=[V_{ir}/f(T_a)+T_a^4]^{1/4},$$

wobei T_s die absolute Temperatur des zu messenden Objekts, V_{ir} das von dem Sensor erzeugte erste elektrische Signal, T_a die absolute Umgebungstemperatur, die von der elektrischen Einrichtung aus dem von der Umgebungstemperatureinrichtung erzeugten anderen elektrischen Signal bestimmt wird, und $f(T_a)$ ein Polynom von T_a darstellt, das wie folgt gegeben ist:

$$f(T_a)=a_0+a_1T_a+a_2T_a^2+a_3T_a+\ldots$$

wobei die Polynomialkoeffizienten a_0, a_1, a_2, a_3... bestimmt werden, indem der Sensor bei bekannter Umgebungstemperatur Objekten mit bekannter Temperatur ausgesetzt wird.

25. Thermometer nach Anspruch 24, wobei das Signal V_{ir} unter Verwendung der folgenden Formel angenähert wird:

$$V_{ir}=f(T_a)\ (T_s^4-T_a^4)$$

26. Thermometer nach einem der vorhergehenden Ansprüche, wobei die Freigabeeinrichtung (16) aufweist:

einen Verschluß (66), der von dem Gehäuse (12) gehalten wird und zwischen einer ersten Stellung, in der eine Übertragung der Strahlung von der Richteinrichtung (14) auf den Sensor (18) blockiert ist, und einer zweiten Stellung, die den Durchgang der Strahlung auf den Sensor erlaubt, bewegbar ist,

eine Einrichtung (68) zum Bewegen des Ver-

schlusses (66) zwischen der ersten und der zweiten Stellung, und
eine Einrichtung (70) zum Steuern der Bewegung des Verschlusses (66), um eine Antwort des Sensors (18) auf die genannte Strahlung freizugeben und die genannte Übergangsantwort auf den Empfang der Strahlung zu bewirken.

27. Thermometer nach Anspruch 26, wobei die Steuereinrichtung (70) eine Bewegung des Verschlusses (66) in die erste Stellung im wesentlichen nach einem Ende der Übergangsantwort freigibt.

28. Thermometer nach Anspruch 26 oder 27, wobei die Steuereinrichtung (68) eine Einrichtung zum Unterdrücken und Absorbieren eines Geräuschs und eines Stoßes aufweist, die bei Bewegung des Verschlusses (66) zwischen der ersten und der zweiten Stellung auftreten.

29. Thermometer nach Anspruch 26, 27 oder 28, wobei das Gehäuse (12) eine Innenkammer (13) aufweist, in der der Sensor (18) enthalten ist, und der Verschluß (66) im thermischen Gleichgewicht mit dem Sensor (18) angebracht ist.

30. Thermometer nach einem der Ansprüche 26 bis 29, mit einer Einrichtung, um der elektrischen Einrichtung (22) Eingabesignale zu liefern, die die Umgebungstemperatur des Sensors (18) angeben, und wobei die Betätigung des Verschlusses (66) die Berechnung des Temperaturdifferentials zwischen dem Sensor (18) und dem Objekt ermöglicht.

31. Thermometer nach einem der Ansprüche 26 bis 30, wobei die elektrische Einrichtung (22) eine Einrichtung zur Antwort auf eine Betätigung des Verschlusses (66) aufweist, um ein Angabesignal zu liefern, das bewirkt, daß die Übergangsantwort gemessen wird.

32. Thermometer nach einem der Ansprüche 26 bis 31, wobei der Verschluß (66) eine geringe thermische Leitfähigkeit zwischen einer ersten Fläche (72), die der Richteinrichtung (14) zugewandt ist, und einer zweiten Fläche (74), die dem Sensor (18) zugewandt ist, aufweist.

33. Thermometer nach Anspruch 32, wobei beide Flächen (72, 74) des Verschlusses (66) gegenüber der genannten Strahlung reflektiv sind.

34. Verfahren zur Messung der Temperatur eines Objekts mit einem Thermometer, das ein Gehäuse (12) aufweist, innerhalb des Gehäuses einen pyroelektrischen Sensor (18) zum Ansprechen auf Infrarotstrahlung zur Erzeugung eines elektrischen Signals trägt, das bei Empfang der genannten Strahlung von dem Objekt entlang eines länglichen Wellenleiters mit einer glatten und glänzenden Innenfläche niedriger.Abstrahlung zur leichteren Übertragung von Infrarotstrahlung und einer Außenfläche vorbestimmter Länge zum Empfang der genannten Infrarotstrahlung von dem Objekt innerhalb des Leiters durch dessen äußeres Ende (32) eine Übergangsantwort zeigt, wobei sichergestellt wird, daß der Leiter wirksam auf den Sensor (18) ausgerichtet ist, der Wellenleiter zur Verbindung mit dem Sensor angeordnet wird, so daß sich dieser im thermischen Gleichgewicht mit jenem befindet, eine vom Gehäuse gehaltene Freigabeeinrichtung verwendet wird, um eine Antwort des Sensors (18) auf die genannte Strahlung zu bewirken, und eine elektrische Einrichtung (22) freigegeben wird, die vom Gehäuse gehalten wird und auf die Übergangsantwort des Signals anspricht, um das Signal unter Gewinnung einer Angabe der tatsächlichen Temperatur des Objekts zu verarbeiten.

35. Verfahren nach Anspruch 34, wobei die Temperatur des zu messenden Objekts unter Verwendung folgender Gleichung berechnet wird:

$$T_s=[V_{ir}/f(T_a)+T_a^4]^{¼},$$

wobei T_s die absolute Temperatur des zu messenden Objekts darstellt, V_{ir} das von dem pyroelektrischen Sensor (18) erzeugte erste elektrische Signal ist, T_a die aus dem zweiten elektrischen Signal bestimmte absolute Umgebungstemperatur ist, und $f(T_a)$ ein Polynom von T_a ist, das durch folgende Gleichung gegeben ist:

$$f(T_a)=a_0+a_1T_a+a_2T_a^2+a_3T_a+\ldots$$

wobei die Polynomialkoeffizienten a_0, a_1, a_2, a_3... bestimmt werden, indem der Sensor bei bekannter Umgebungstemperatur Objekten mit bekannten Temperaturen ausgesetzt wird.

36. Verfahren nach Anspruch 35, wobei das Signal V_{ir} unter Verwendung folgender Formel angenähert wird:

$$V_{ir}=f(T_a)\ (T_s^4-T_a^4).$$

37. Verfahren nach einem der Ansprüche 34 bis 36, wobei die Empfindlichkeit des pyroelektrischen Sensors (18) kalibriert wird, bevor dieser wahlweise Infrarotstrahlung von dem zu messenden Objekt ausgesetzt wird.

38. Verfahren nach Anspruch 37, wobei der pyroelektrische Sensor (18) zur Darstellung piezoelektrischer Eigenschaften eingerichtet und seine Empfindlichkeit kalibriert wird, mit folgenden Schritten:

Anlegen eines vorbestimmten Kalibrierungssignals an den pyroelektrischen Sensor, um zu bewirken, daß dieser ein elektrisches Antwort-Kalibrierungssignal erzeugt, und
Korrigieren des von dem pyroelektrischen Sensor erzeugten ersten elektrischen Signals aufgrund des elektrischen Antwort-Kalibrierungssignals und eines vorbestimmten Standardwerts.

39. Verfahren nach Anspruch 38, wobei die Kalibrierung der Empfindlichkeit des pyroelektrischen Sensors (18) folgende Schritte aufweist:

Anlegen eines vorbestimmten Pegels Infrarotstrahlung an den pyroelektrischen Sensor, um zu bewirken, daß dieser ein elektrisches Antwort-Kalibrierungssignal erzeugt, und
Korrigieren des von dem pyroelektrischen Sensor erzeugten ersten elektrischen Signals aufgrund des elektrischen Antwort-Kalibrierungssignals und eines vorbestimmten Standardwerts.

Revendications

1. Thermomètre comprenant :

un boîtier (12),
un capteur pyroélectrique (18) supporté à l'intérieur dudit boîtier (12) et sensible à un rayonnement infrarouge afin de générer un signal électrique qui présente une réponse transitoire lors de la réception dudit rayonnement,
un moyen directeur (14), supporté par ledit boîtier (12), en alignement optique avec ledit capteur (18), destiné à diriger le rayonnement infrarouge provenant d'un objet (11), dont la température réelle doit être mesurée, afin qu'il soit incident sur ledit capteur (18), ledit moyen directeur (14) comprenant un guide d'onde allongé (14) de longueur prédéterminée présentant une extrémité externe (32) afin de recevoir un rayonnement infrarouge provenant de l'objet devant être mesuré et une extrémité interne (33) en alignement fonctionnel avec le capteur (18), ledit guide d'onde (14) étant interconnecté audit capteur (18) de façon à être en équilibre thermique avec celui-ci et présentant une surface intérieure lisse et brillante (30) d'un faible coefficient d'émission afin de faciliter la transmission d'un rayonnement infrarouge,
un moyen de validation (16), supporté par ledit boîtier (12), destiné à permettre une réponse dudit capteur (18) audit rayonnement,
et un moyen électrique (22) supporté par ledit boîtier (12) et sensible à ladite réponse transitoire dudit signal, destiné à traiter ledit signal de façon à élaborer une indication de la température réelle dudit objet (11).

2. Thermomètre selon la revendication 1, dans lequel ledit moyen directeur (14) est en lui-même de faible coefficient d'émission vis-à-vis du rayonnement infrarouge afin de réduire sa contribution au rayonnement dirigé vers ledit capteur (18).

3. Thermomètre selon la revendication 1 ou 2, dans lequel ledit moyen directeur (14) présente un isolement thermique substantiel vis-à-vis des sources de chaleur ambiantes externes audit moyen directeur (14).

4. Thermomètre selon l'une quelconque des revendications précédentes, dans lequel ledit capteur (18) est un élément pyroélectrique (44) pris en sandwich entre une première électrode (52) disposée en utilisation de façon à être en regard dudit objet (11) et une secondé électrode (54) sur la surface opposée dudit élément, ladite première électrode (52) présentant la caractéristique d'un coefficient d'émission et d'une absorption élevés pour ledit rayonnement infrarouge.

5. Thermomètre selon l'une quelconque des revendications 1 à 3, dans lequel ledit capteur (18) est un élément pyroélectrique (44) pris en sandwich entre une première électrode (52) disposée en utilisation de façon à être en regard dudit objet (11) et une seconde électrode (54) sur la surface opposée dudit élément, et dans lequel ladite seconde électrode (54) n'est pas transparente audit rayonnement infrarouge et est fortement réfléchissante pour celui-ci.

6. Thermomètre selon l'une quelconque des revendications 1 à 3, dans lequel ledit capteur (18) est un élément pyroélectrique (44) pris en sandwich entre une première électrode (52) disposée en utilisation de façon à être en regard dudit objet (11) et une seconde électrode (54) sur la surface opposée dudit élément, et dans lequel ladite première électrode (52) est transparente au rayonnement infrarouge lointain et ladite seconde électrode (54) est substantiellement réfléchissante pour celui-ci.

7. Thermomètre selon l'une quelconque des revendications précédentes, dans lequel ledit moyen directeur (14) est agencé de façon à délivrer un rayonnement infrarouge provenant dudit objet à l'intérieur

d'un angle de vue prédéterminé et pour réaliser l'impact dudit rayonnement sur ledit capteur (18) sur une surface relativement large.

8. Thermomètre selon l'une quelconque des revendications précédentes, dans lequel ledit moyen électrique (22) devient automatiquement insensible à d'autres signaux d'entrée provenant dudit capteur (18) après la réception de ladite réponse transitoire.

9. Thermomètre selon l'une quelconque des revendications précédentes, dans lequel ledit moyen électrique (22) comprend un moyen destiné à calculer la température absolue dudit objet grâce à une intégration du niveau de ladite réponse sur une tranche de temps fixe.

10. Thermomètre selon l'une quelconque des revendications précédentes, dans lequel ledit capteur (18) présente ledit transitoire en réponse à une impulsion isolée dudit rayonnement, et dans lequel ledit moyen électrique (22) ne répond qu'à ladite impulsion isolée.

11. Thermomètre selon l'une quelconque des revendications précédentes, dans lequel ledit capteur (18) est monté à l'intérieur dudit boîtier (12), et dans lequel ledit boîtier (12) comprend un moyen (150, 160) destiné à égaliser la pression des deux côtés dudit capteur (18).

12. Thermomètre selon l'une quelconque des revendications précédentes, dans lequel un élément chauffant (108) est supporté par ledit boîtier (12) dans une position afin de fournir de la chaleur audit capteur (18) et fournir un niveau d'étalonnage infrarouge stable imposé audit capteur, et dans lequel ledit moyen électrique (22) répond audit capteur (18) lorsqu'il est chauffé par ledit élément chauffant (108).

13. Thermomètre selon l'une quelconque des revendications précédentes, dans lequel ledit moyen électrique (22) comprend un microprocesseur (76) comprenant une mémoire électronique qui contient une table prédéterminée de données de correction conformément à des sources d'erreur possibles connues et des modifications des caractéristiques de réponse dudit capteur (18), ledit moyen électrique (22) étant programmé pour ajuster la température absolue calculée dudit objet (11) conformément auxdites données de correction.

14. Thermomètre selon l'une quelconque des revendications précédentes, dans lequel ledit moyen directeur (14) comprend un moyen (36) sur ladite surface externe (34) en vue d'isoler thermiquement ladite surface externe (34) des sources de chaleur ambiantes externes.

15. Thermomètre selon la revendication 14, dans lequel ledit moyen (36) destiné à isoler thermiquement comprend un revêtement thermo-isolant sur ladite surface externe.

16. Thermomètre selon l'une quelconque des revendications précédentes, dans lequel ledit capteur (18) est sensible à un signal d'étalonnage électrique prédéterminé,

dans lequel ledit moyen électrique (22) comprend un moyen destiné à appliquer audit capteur ledit signal d'étalonnage électrique,

et dans lequel ledit moyen électrique (22) répond à la sortie du capteur provenant dudit signal d'étalonnage en corrigeant le calcul de ladite température réelle.

17. Thermomètre selon la revendication 16, dans lequel ledit moyen électrique (22) est agencé pour augmenter la surface de sensibilité dudit capteur (18) audit rayonnement d'une quantité prédéterminée après la réponse audit signal d'étalonnage.

18. Thermomètre selon la revendication 16 ou 17, dans lequel ledit capteur (18) est un élément pyroélectrique (44) pris en sandwich entre une première électrode (52) disposée de façon à être en regard dudit objet (11) et une seconde électrode (54) sur la surface opposée dudit élément, et dans lequel l'une desdites électrodes (52, 54) comprend deux segments d'électrodes séparés et espacés (98, 100) où lesdits segments sont inclus dans ledit moyen d'application.

19. Thermomètre selon la revendication 18 qui comprend en outre un moyen (102) destiné à interconnecter lesdits segments (98, 100) avant ladite réponse dudit capteur (18) audit rayonnement.

20. Thermomètre selon l'une quelconque des revendications précédentes, qui comprend en outre un moyen (20) supporté par ledit boîtier (12) et sensible à la température ambiante dudit capteur (18) avant ladite réception initiale dudit rayonnement afin de générer un autre signal électrique représentatif de ladite température ambiante, et dans lequel ledit moyen électrique (22) traite ledit autre signal électrique afin de calculer la température réelle dudit objet.

21. Thermomètre selon la revendication 20, dans lequel ledit boîtier définit une chambre intérieure, et dans lequel ledit moyen de température ambiante (20) est également disposé à l'intérieur de ladite chambre en équilibre thermique avec ledit capteur (18).

22. Thermomètre selon la revendication 20 ou 21, dans lequel ledit moyen de température ambiante (20) présente son signal électrique avec une réponse lente par comparaison à la réponse dudit capteur (18) audit rayonnement.

23. Thermomètre selon la revendication 20 ou 21 ou 22, dans lequel ledit moyen de température ambiante (20) est monté à l'intérieur d'une cavité définie à l'intérieur d'un boîtier (164) par ledit capteur (18).

24. Thermomètre selon l'une quelconque des revendications 20 à 23, dans lequel la température de l'objet à mesurer par ledit moyen électrique (22) est calculée en utilisant l'équation :

$$T_s = [V_{ir} / f(T_a) + T_a^{4}]^{1/4},$$

où T_s représente la température absolue de l'objet à mesurer, V_{ir} représente le premier signal électrique généré par ledit capteur, T_a représente la température ambiante absolue déterminée par ledit moyen électrique à partir dudit autre signal électrique généré par ledit moyen de température ambiante, et $f(T_a)$ représente un polynôme en T_a donné par l'équation :

$$f(T_a) = a_0 + a_1T_a + a_2T_a^{2} + a_3T_a + ...,$$

où les coefficients du polynôme a_0, a_1, a_2, a_3 ... sont déterminés en exposant ledit capteur à une température ambiante connue, à des objets présentant des températures connues.

25. Thermomètre selon la revendication 24, dans lequel le signal V_{ir} est approché par approximation en utilisant la formule :

$$V_{ir} = f(T_a) (T_s^{4} - T_a^{4}).$$

26. Thermomètre selon l'une quelconque des revendications précédentes, dans lequel ledit moyen de validation (16) comprend :

un obturateur (66) supporté par ledit boîtier (12) et mobile entre une première position, empêchant la transmission dudit rayonnement depuis ledit moyen directeur (14) vers ledit capteur (18), et une seconde position qui permet le passage dudit rayonnement vers ledit capteur,
un moyen (68) destiné à déplacer ledit obturateur (66) entre lesdites première et seconde positions,
et un moyen (70) destiné à commander le déplacement dudit obturateur (66) afin de permettre une réponse dudit capteur (18) audit rayonnement pour présenter ladite réponse transitoire lors de la réception dudit rayonnement.

27. Thermomètre selon la revendication 26, dans lequel ledit moyen de commande (70) permet le déplacement dudit obturateur (66) vers ladite première position principalement à la fin de ladite réponse transitoire.

28. Thermomètre selon la revendication 26 ou 27, dans lequel ledit moyen de commande (68) comprend un moyen destiné à réduire et à absorber les bruits et les chocs produits lors du déplacement dudit obturateur (66) entre lesdites première et seconde positions.

29. Thermomètre selon la revendication 26 ou 27 ou 28 dans lequel ledit boîtier (12) comprend une chambre intérieure (13) dans laquelle ledit capteur (18) est contenu, et dans lequel ledit obturateur (66) est monté de manière à être en équilibre thermique avec ledit capteur (18).

30. Thermomètre selon l'une quelconque des revendications 26 à 29 qui comprend un moyen destiné à fournir audit moyen électrique (22) des signaux d'entrée indicatifs de la température ambiante dudit capteur (18), et dans lequel l'actionnement dudit obturateur (66) permet le calcul de la différence de température entre ledit capteur (18) et ledit objet.

31. Thermomètre selon l'une quelconque des revendications 26 à 30, dans lequel ledit moyen électrique (22) comprend un moyen destiné à répondre à l'actionnement dudit obturateur (66) de manière à fournir un signal d'indication qui amène ladite réponse transitoire à être mesurée.

32. Thermomètre selon l'une quelconque des revendications 26 à 31, dans lequel ledit obturateur (66) présente une faible conductivité thermique entre une première surface (72) qui est en regard dudit moyen directeur (14) et une seconde surface (74) qui est en regard dudit capteur (18).

33. Thermomètre selon la revendication 32, dans lequel lesdites deux surfaces (72, 74) dudit obturateur (66) réfléchissent ledit rayonnement.

34. Procédé destiné à mesurer la température d'un objet à l'aide d'un thermomètre comportant un boîtier (12), supportant un capteur pyroélectrique (18) à l'intérieur du boîtier de façon à être sensible au rayonnement infrarouge en vue de générer un signal électrique qui présente une réponse transitoire

lors de la réception dudit rayonnement provenant de l'objet le long d'un guide d'onde allongé présentant une surface intérieure lisse et brillante de faible facteur d'émission afin de faciliter la transmission de rayonnement infrarouge, et une surface extérieure, qui est de longueur prédéterminée en vue de recevoir ledit rayonnement infrarouge provenant de l'objet à l'intérieur du guide à travers une extrémité externe (32) de celui-ci, en assurant que le guide est en alignement fonctionnel avec le capteur (18) en s'arrangeant pour que le guide d'onde soit relié au capteur de sorte que le capteur soit en équilibre thermique avec celui-ci, en utilisant un moyen de validation supporté par le boîtier pour permettre une réponse dudit capteur (18) audit rayonnement, et en validant un moyen électrique (22) supporté par ledit boîtier et qui est sensible à ladite réponse transitoire dudit signal de façon à traiter ledit signal afin d'élaborer une indication de la température réelle dudit objet.

35. Procédé selon la revendication 34, comprenant le calcul de la température de l'objet à mesurer en utilisant l'équation :

$$T_s = [V_{ir} / f(T_a) + T_a^4]^{1/4},$$

où T_s représente la température absolue de l'objet à mesurer, V_{ir} représente le premier signal électrique généré par ledit capteur pyroélectrique (18), T_a représente la température ambiante absolue déterminée à partir dudit second signal électrique, et f (T_a) représente un polynôme en T_a donné par l'équation :

$$f(T_a) = a_0 + a_1T_a + a_2T_a^2 + a_3T_a + \ldots,$$

où les coefficients du polynôme a_0, a_1, a_2, a_3 ... sont déterminés en exposant ledit capteur pyroélectrique à une température ambiante connue à des objets présentant les températures connues.

36. Procédé selon la revendication 35, comprenant l'approximation du signal V_{ir} en utilisant la formule :

$$V_{ir} = f(T_a)\,(T_s^4 - T_a^4).$$

37. Procédé selon l'une quelconque des revendications 34 à 36, comprenant l'étalonnage de la sensibilité dudit capteur pyroélectrique (18) avant d'exposer sélectivement ledit capteur pyroélectrique audit rayonnement infrarouge provenant de l'objet à mesurer.

38. Procédé selon la revendication 37, comprenant l'adaptation dudit capteur pyroélectrique (18) pour présenter des propriétés piézoélectriques et l'étalonnage de la sensibilité dudit capteur pyroélectrique comprenant:

l'application d'un signal d'étalonnage prédéterminé audit capteur pyroélectrique de façon à amener ledit capteur pyroélectrique à générer un signal d'étalonnage électrique sensible,

et la correction dudit premier signal électrique généré par ledit capteur pyroélectrique sur la base dudit signal d'étalonnage électrique sensible et d'une valeur de référence prédéterminée.

39. Procédé selon la revendication 38, dans lequel l'étalonnage de la sensibilité dudit capteur pyroélectrique (18) comprend :

l'application d'un niveau prédéterminé de rayonnement infrarouge audit capteur pyroélectrique de façon à amener ledit capteur pyroélectrique à générer un signal d'étalonnage électrique sensible,
et la correction dudit premier signal électrique généré par ledit capteur pyroélectrique sur la base dudit signal d'étalonnage électrique sensible et d'une valeur de référence prédéterminée.

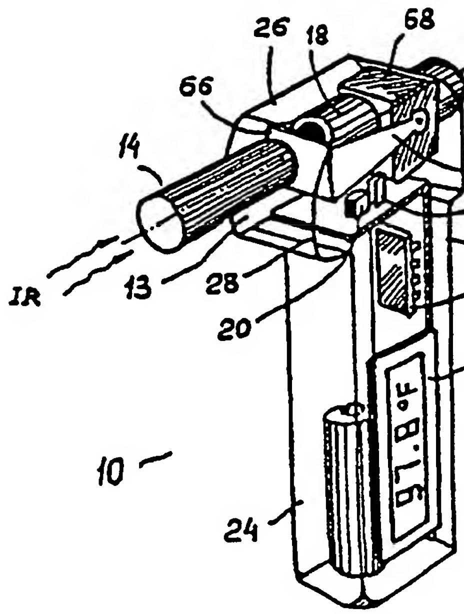
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Fig. 1

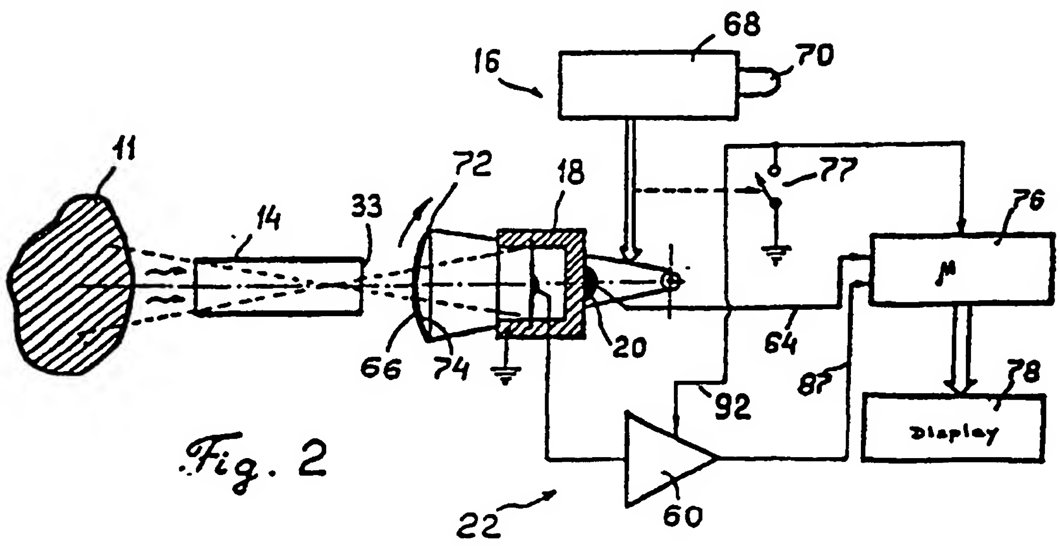
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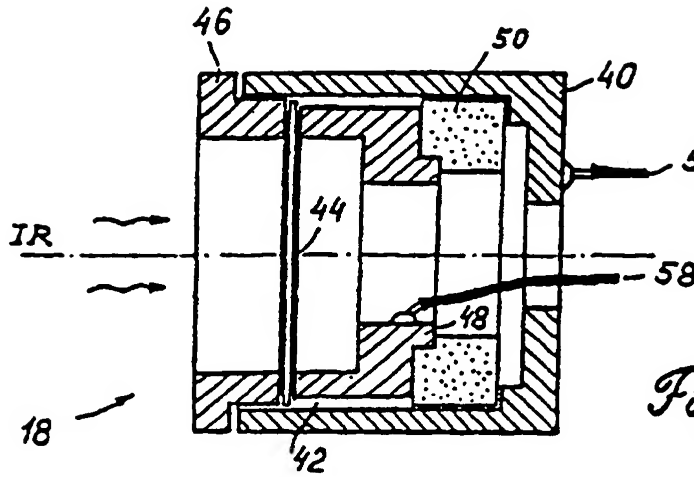
Fig. 2



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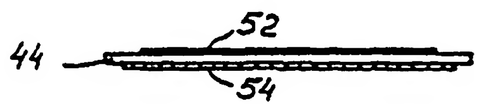

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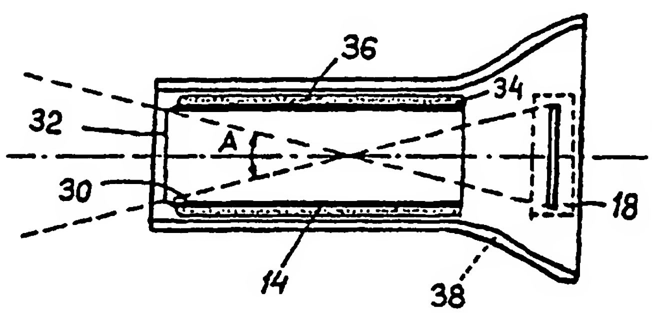

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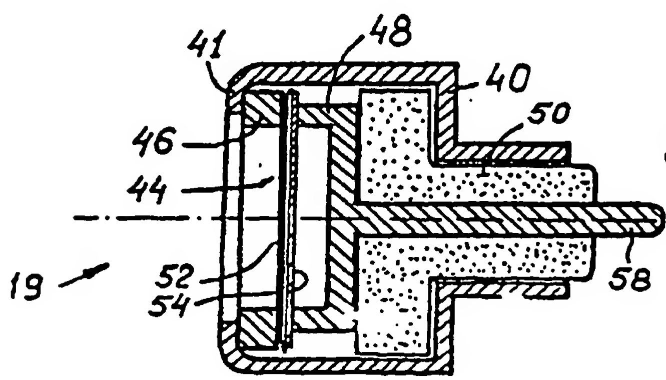
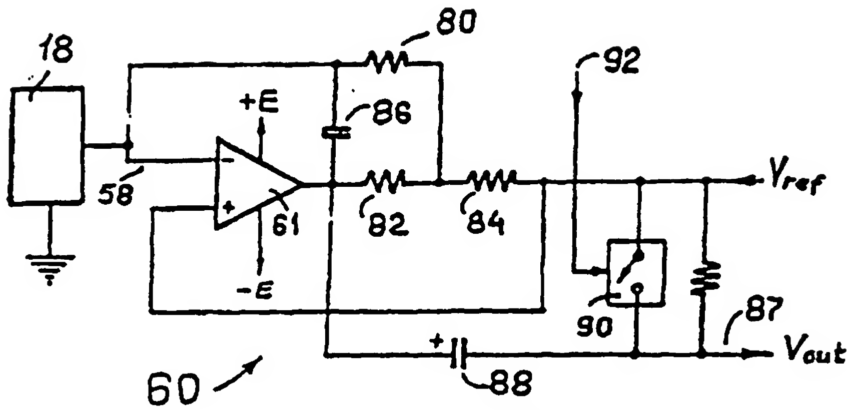


Fig. 5



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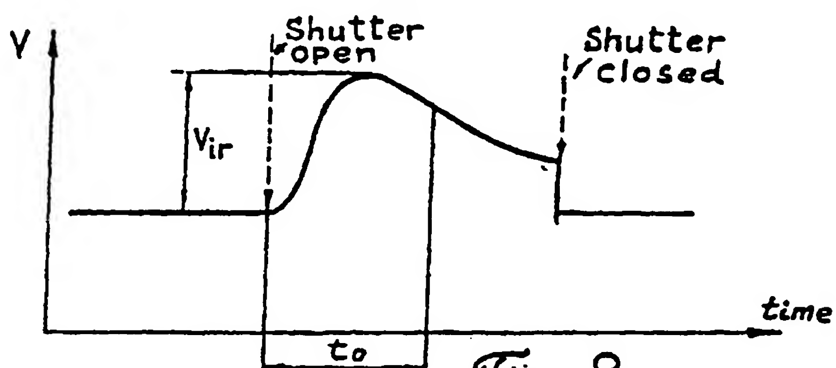

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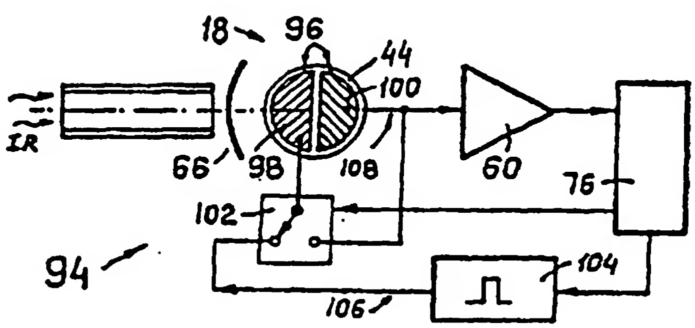


Fig. 9

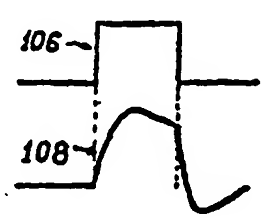
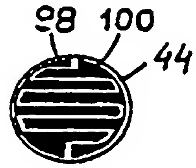


Fig. 10

Fig. 11



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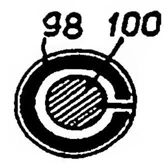

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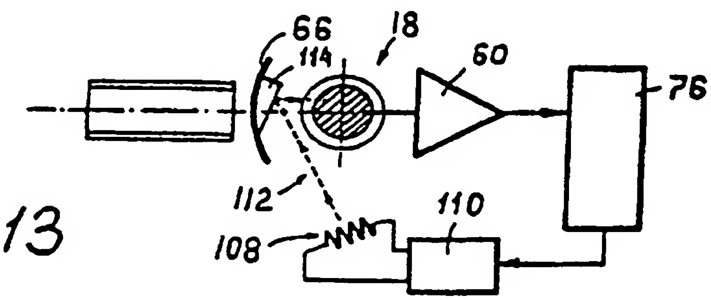


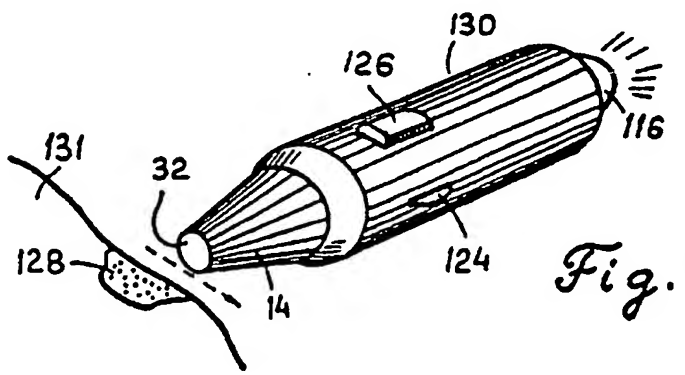
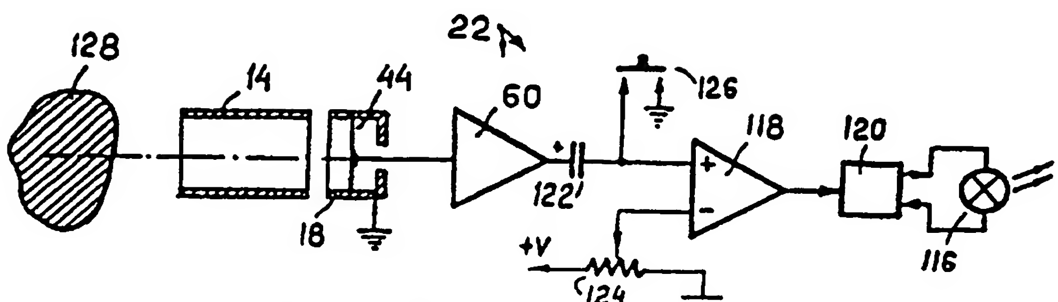


Fig. 14



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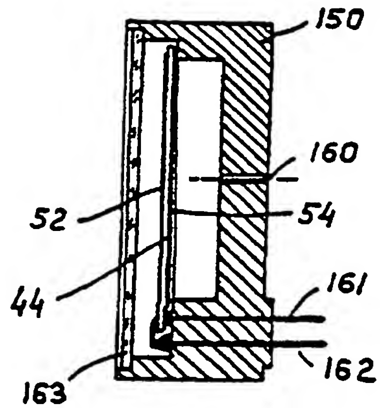

Fig. 16

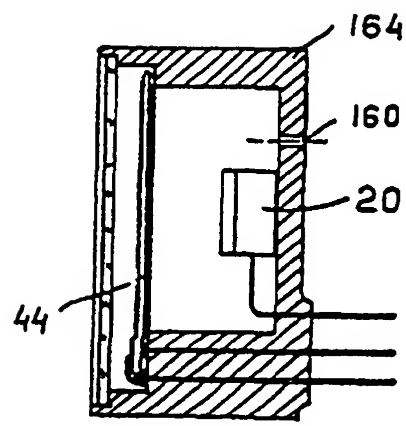

Fig. 17